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ABSTRACT

This study used a five-step procedure to establish and validate the essential competencies in computer literacy for elementary and secondary school (grades K-12) science teachers. This procedure produced a concise list of 24 competencies that are not only representative of the broad field of computer literacy skills, but also are considered to be essential for science teachers. These competencies fall into the categories of: computer awareness; applications of microcomputers in science education; implementing microcomputers in science teaching; selection and evaluation of software; and resources for educational computing. (Computer programming, the history of computing, and computers and society were not rated as essential competencies.) The 24 competencies will be used to develop: (1) a test for measuring the computer literacy of science teachers; and (2) a curriculum for training science teachers to use the computer. The test and the curriculum will be used by both preservice and inservice science teachers to successfully implement educational computing. Tables showing factors for essential computer literacy competencies and providing descriptive statistics for 24 essential and 21 secondary competencies are included. (Author/JN)

DEVELOPMENT AND VALIDATION OF ESSENTIAL COMPUTER LITERACY COMPETENCIES FOR SCIENCE TEACHERS

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ABSTRACT

This study used a five-step procedure to establish and validate the essential competencies in computer literacy for science teachers (K-12). That rigorous procedure produced a concise list of 24 competencies that are not only representative of the broad field of computer literacy skills, but that also have been condensed to those competencies that are essential for science teachers.

The essential competencies in computer literacy reported in this study will be used to develop a) a test for measuring the computer literacy of science teachers, and b) a curriculum for training science teachers to use the computer. The test and curriculum will be used by both preservice and inservice science teachers to successfully implement educational computing.

Project ENLIST Micros will Encourage Literacy of Science Teachers in the use of Microcomputers by developing models and materials for training science teachers to use the computer in the classroom. This study reports on the project's first phase: the development and validation of essential competencies in computer literacy for science teachers.

BACKGROUND

The sector of our society devoted to information technology has grown rapidly since World War II. Information-based industry now accounts for more than 50% of the labor force and more than 50% of the Gross National Product (Molnar, 1981). Knowledge is becoming the principle resource of our nation and the world. As society changes from an industrial base to an information base, the skills and knowledge necessary to function in society also change. That fundamental shift has direct implications for education (Ellis, 1984).

In the industrial era, the purpose of public schooling was to teach those skills--reading and writing--necessary for people to function in an industrial society. Possession of information was of paramount importance and libraries flourished. But what does it mean to be literate in an information society? Libraries have difficulty collecting and maintaining even a small part of the world's knowledge. Possession of information seems no longer paramount; rather, access to and use of information becomes critically important (Hade, 1982). Thus, the purpose of public schooling shifts from the basics of reading and writing to teaching the basics of accessing and using information.

With the phenomenal growth of information, the computer has become an essential tool for organizing and accessing this information. Just as the engine was the important machine for the industrial era, the computer has become the crucial machine for the information era. Rarely a day goes by without indirect or direct contact with a computer. The NSF points out that "as the computer becomes a part of the home, school, and business landscape, people will need to know how to make intelligent, productive, and creative use of it" (NSF, 1979 p. 23). Computer literacy is rapidly becoming one of the basic skills required for full participation in the emerging information society. If educators fail to address the issue of computer literacy, a new class of disadvantaged learners may emerge, "those who lack the skills to exploit microelectronic information resources and synthesize the findings" (Hurd, 1982 p. 11).

Public education must ensure computer literacy for all citizens. The process appears well underway, if one judges from the growing numbers of microcomputers that can be found in the schools. A Rand Corporation report (1984) documented a 230% gain in microcomputer units in schools between 1980 and 1982--increasing from some 30,000 machines to 100,000. However, this translates to less than one for every school, one for every 20 classrooms, or one for every

420 students (Rand, 1984). Yet the acquisition of machines by schools is increasing. Anderson (1983) reported that if the growth rate continues 85% of schools would be users in 1983. The growing numbers of microcomputers in schools is a mixed blessing compounded by the lack of teachers trained to use them appropriately in the classrooms. Gary Watts (1984, p. 5), speaking for the National Education Association, has argued:

> If computers are to make a positive and lasting contribution to learning then teachers must be full partners in the computerization of our nation's classrooms.

However, Okey (1984, p. 14) recently pointed out, "Most teachers in our schools, including science and mathematics teachers, have few computing skills."

Science teachers must be computer literate to use the microcomputer as an instructional tool, to introduce students to using the microcomputer to solve problems in science, to facilitate the development of computer literacy by students, to use the microcomputer as a tool to increase the efficiency of management of instruction, and to develop and exhibit positive attitudes and values toward computer use. Therefore, if we are to succeed in training students for the information age, we must train science teachers to use computers effectively in their teaching. Science teachers must learn to use the computer in instruction, just as they have learned to use textbooks, films, television, and the overhead projector. However, as Watson (1983) has pointed out, few science teachers have been trained in how to use the computer for instructional purposes or participated in instruction using a computer. Although some teacher education programs may help science teachers learn about the computer, all teacher educators face difficult decisions as they attempt to decide, for example, "whether teachers should be familiar with computer simulations or be able to design simulations. That is, should science teachers merely know where to obtain computer software or should they know how to improve

inadequate software?" (NIE, 1984, p. 270). What are the essential competencies in computer literacy for science teachers? Furthermore, what might constitute a curriculum for training science teachers to use the computer in the classroom?

The problem of selecting objectives for a computer literacy curriculum is the same as deciding on objectives or goals for any curriculum. Curriculum development is a well-established discipline within the educational enterprise. The process of curriculum development begins with the specification of program goals and the identification of program objectives and includes the research and application of relevant literature. The complete process, as developed and followed by the Biological Science Curriculum Study, has been described in detail by Mayer (BSCS, 1976).

PROBLEM

From what has already been stated, one goal of science teacher preparation is clear: science teachers must be taught how to use the computer in their teaching. They must become computer literate. But what constitutes computer literacy for science teachers? What are the program objectives (i.e. competencies) for a curriculum that would train teachers how to use the microcomputer in the classroom?

There is little consensus among educators about the definition of computer literacy. Perhaps computer literacy is different for students, computer professionals, and educators. Is computer literacy the same for a science teacher as it is for other teachers? The purpose of this study was to determine the essential competencies in computer literacy for science teachers. Once determined, they could then be used to establish objectives for and to assist in the design of an appropriate computer literacy curriculum for science teachers.

PROCEDURE AND FINDINGS

A five-step process was used to determine the essential computer-literacy competencies for science teachers. The goal of this process was to derive a list of competencies that has validity and that is parsimonious. The validity of the competencies was established by ensuring that all potentially important competencies were considered (steps one and two) and by conducting a prioritization by individuals involved in implementing microcomputers in science teaching--science teachers, principals, and experts in educational computing in the sciences (step three). The identification of a parsimonious list of competencies was achieved by condensing the final list of competencies to those that were rated important (step four). To condense the list of competencies further, a factor analysis procedure was used to reduce the essential competencies to a few scales that explain the computer literacy requirements for a science teacher (step five). Those scales will be used to develop a mastery test and five instructional modules on computer literacy for science teachers.

Step One: Assembling the Pool of Competencies

The authors conducted an extensive literature review, along with input from science and computer educators, to develop a comprehensive list of eligible competencies. A Dialog search of the ERIC data base yielded 26 articles dealing with computer literacy and science education. Additional manual searches were conducted of the proceedings of all National Educational Computing Conferences and Association for Educational Data Systems conventions, all issues of the Journal of Computers in Mathematics and Science Teaching, and various state documents listing computer literacy competencies. In addition, 10 science

educators and computer educators were asked to submit a personal list of computer literacy competencies for science teachers. The competencies identified through the literature review and from the computer experts were combined into a comprehensive list containing 160 statements.

Step Two: Analysis Via Qualitative Procedures

Two qualitative procedures were used to condense the list of 160 eligible competencies. There was considerable overlap among the 160 competencies; as a result, they were consolidated into a list of 58 competencies that were believed by the project staff to account for all of the information contained in the larger list. Original wording of the competency statements was used whenever possible.

A second procedure was used to verify that the consolidated list of 58 competencies accounted for all the information contained in the original list. Five computer experts and science educators compared the consolidated list with the original list. Through that process two of the statements on the consolidated list were combined into one and six more were added from the original list. For each competency on the final list of 63, a majority of the reviewers agreed that the competency represented information in the larger list and that no other competencies were needed. Thus, the reviewers and the project staff believed the new list of 63 competencies represented the comprehensive field of computer literacy for science teachers.

Step Three: The Prioritization of the Competencies

The third step was to prioritize the competencies by conducting a survey of three groups involved in implementing educational computing in science teaching--science teachers, school administrators, and experts in educational computing,

and science education. The 46 experts were identified through a search of the literature; those experts represented project directors, authors, and consultants in educational computing. One hundred and forty-six secondary science teachers and 65 elementary principals responded to the survey. Table 1 lists the mean or percentage for descriptive variables for each group.

The respondents were asked to rate each competency on the level of importance using a five point Likert-type scale ranging from very important to very unimportant. Descriptive statistics were calculated for each competency for each group and the combined groups. Table 2 lists the competencies in descending order for the percentage of combined respondents that indicated that the competency was either important or very important. The mean and standard deviation are also provided for each competency for each group and the combined groups. The maximum value for a competency is four and the minimum is zero--corresponding to very important and not very important respectively. A one-way analysis of variance was performed for each competency using the groups as the independent variable.

Since there is considerable disagreement in the literature over the importance of specific competencies such as programming, we anticipated that significant differences would be found among teachers, administrators, and experts for many of the competencies. Surprisingly, only eight out of the 63 competencies were rated significantly different ($p < .01$) by the groups (Table 2). The high consensus on 87% of the competencies strengthens claims that the 63 competencies are valid indicators of the skills science teachers need to use microcomputers successfully in the classroom.

Step Four: Reduction to Essential Competencies

For a competency to be selected as essential, 75% or more of the respondents had to indicate that it was either important or very important. The criterion of 75% was selected because it represented a high consensus for the importance of the competency. The reason for setting it at that high level was to reduce the competencies to those most essential for successful use of microcomputers in the science classroom. Twenty-four competencies met that criterion and are the primary goals for the ENLIST Micros curriculum.

However, another 21 competencies were also ranked as important by a majority of the respondents and have become secondary goals. Three criteria were used to determine the set of secondary goals: the competency must have less than 75% of the respondents rating it as important or very important, the competency must have greater than 50% of the respondents rating it as important or very important, and the competency must have a mean for all respondents greater than 2.50 (midway between neutral and important). The secondary goals may be used to guide the development of optional enrichment and remediation instructional materials. However, the determination of mastery of the competencies by science teachers will be based solely on the 24 essential competencies. The remaining 18 competencies that were not selected as primary or secondary goals were eliminated because of time constraints; the time allowed for the mastery of the curriculum is 15 hours.

The essential competencies will be explained more completely in step five. However, it is worthwhile to examine the competencies that were not ranked important by more than 75% of the respondents. Included in the 18 low-rated competencies were items that can be logically grouped into two categories: competencies that are traditionally included in introductory courses on computer science and competencies that apply to educational computing, but are not

required for initial implementation. Eleven low-rated competencies (32, 60, 36, 35, 59, 31, 54, 50, 58, 57, and 20) address topics commonly taught in computer literacy courses for students and teachers: computer programming, the nomenclature of computing, the components and functions of a computer system, the impact of computers on society, and the history of computing. Seven other low-rated competencies (7, 5, 51, 16, 41, 48, and 63) address knowledge and skills of educational computing that are not required to use microcomputers initially in the classroom, but that might be important to a teacher who wants to specialize in educational computing: knowledge of components of educational computing systems, knowledge of procedures and aides to design instructional software, and effects of computer use on education, schools, and students.

Especially interesting is the discrepancy in ratings by the different groups of several competencies not ranked as essential. Items 7, 5, 51, 16, 41, and 57 deal with more advanced skills and knowledge in educational computing; these statements were ranked lower by teachers than by the experts and principals. Analysis of variance revealed a significant difference ($p < .01$) between groups for item 5, which addresses the effects of computer use on student learning; only in the case of teachers did fewer than 50% of the respondents in a group rate that objective as less than important. Perhaps concerns about student learning with computers and concerns about sophisticated knowledge and skills of educational computing develop with prolonged involvement with computers.

The Concerns Based Adoption Model (CBAM) of educational change, originally conceptualized by Fuller (1969), has found that concerns about consequences are initially low and concerns about management are initially high when a teacher first implements an innovation. With prolonged use of an innovation, concerns about consequences and refinement of use gradually predominate among teachers.

Often three to five years pass before consequences emerge as the greatest concern; perhaps the teachers responding to the survey have been using microcomputers in the classroom for only a few years, because educational computing is a recent innovation. Therefore, even though some items are ranked as not important by most teachers, those items should be included in the training materials if the experts rate them highly. The experts may reflect concerns that teachers might exhibit after prolonged use of the microcomputer.

Because some of the competencies not selected as essential may be appropriate for science teachers that are experienced users of microcomputers, closer examination of the competencies categorized as secondary goals and in some cases as low-rated also is warranted. Seven competencies ranked lower by teachers are important to more experienced users of educational computers. Items 56, 14, 62, and 6 focus on how to promote learning with computers and how to improve problem-solving skills. The other three items (45, 33, and 9) are skills that a teacher who is a school leader would need to facilitate the use of computers by other teachers. Those seven competencies may be included in the ENLIST Micros curriculum; however, if included, those competencies will be optional, because they are unnecessary for the initial implementation of educational computing and may distract teachers who are unfamiliar with using microcomputers in the classroom. Because those competencies may be important to more advanced users, they may be addressed in the curriculum as teachers develop those higher levels of concerns.

Step Five: Determination of Factor Scales

Factor analysis was used to "uncover the independent sources of data variation" (Rummel, 1970, p.16). The dimensions disclosed by the factor analysis can be interpreted as measures of the amount of ordered or patterned variation in the responses to the competencies. The factor analysis application used for

this study was "the exploration and detection of patterning of variables with a view to discovery of new concepts and a possible reduction of data" (Nie, et al., 1975, p. 469).

Prior to completing the descriptive analysis, we assumed that a separate factor analysis would be performed for each group; the comparison of those separate analyses would describe the similarity of the groups. However, because responses to only eight of the competencies (four out of the 24 essential competencies) differed significantly between groups (Table 2), we decided that there was too little difference between the groups for the competencies to warrant separate analyses. Therefore, all groups were combined for the factor analysis.

The factor analysis was conducted using the 24 essential competencies that are the primary goals of the curriculum and the only ones used to determine mastery. There were 2[illegible] cases and 24 variables used in the analysis. R-factor analysis, in which the correlation matrix represents correlations between variables, was used as the method of analysis. Principal factor iteration, available with SPSS^{X}, (SPSS, 1983) was used as the method to extract the initial factors for the unrotated matrix. At present this is the most widely accepted factoring method (Nie, et al., 1975, p. 480). The initial-factor matrix was used to decide the number of factors that would be retained for the subsequent analysis. A minimum eigenvalue of 1.0 was used as the criterion for rejecting factors. Eight factors were thus derived that explained 41.9% of the variance among the 24 competencies.

The last step was to rotate the factor matrix to a terminal solution; the varimax method of rotation was used to simplify the structure of the factor matrix. The resulting orthogonal factors had high loadings for the fewest variables for each factor, thus simplifying the interpretation. A minimum

factor loading of .3 was used as a meaningful level of contribution of a variable to a factor to warrant including the variable in the factor.

Table 3 presents the eight factors derived for the factor analysis. Two variables did not load on any factor at a level greater than .30 (item 10 and item 55). We propose that factors 3 and 8 can be combined for a module on Implementing Microcomputers in Science Teaching, factors 2 and 7 can be combined for a more general module on Applications of Microcomputers in Science Education, and factors 1 and 6 can be combined for a general module on Computer Awareness. Factor 4 could become the basis for a module on Selection and Evaluation of Computer Software. Factor 5 focuses on general attitudes about educational computing and will be infused into all modules.

Prior to the data analysis, we established tentative categories for five teacher training modules. This was based on a preliminary sample of the total data and was done descriptively rather than statistically because of the small sample size. The *a priori* titles were: Computer Awareness, Educational Uses of the Microcomputer, Integration of the Microcomputer into Instruction, Evaluation of Software, and Resources in Educational Computing. The titles were also reflective of our belief that modules on these areas should constitute the essential knowledge that science teachers should know in order to use the computer effectively in the classroom.

What is especially interesting is the degree to which the factors derived from the factor analysis correspond with the titles for the five modules for ENLIST Micros tentatively set prior to the analysis. To a major extent, the differences are in title only, but do reflect a refinement only possible through factor analysis. The Computer Awareness module remains intact (factors 1 and 6). The former educational uses module is now replaced by the applications module (factors 2 and 7). The integration into instruction module is now replaced by

the module titled Implementing Microcomputers in Science Teaching (factors 3 and 8). The Evaluation of Software module has been expanded to include selection of software in the newly titled module, Selection and Evaluation of Software (factor 4).

Only one module, Resources in Educational Computing, tentatively identified prior to the study was not indicated by the analysis. However, item 49, which dealt with sources of information about computer uses in education was ranked important by more than 65% of all respondents. In addition, the mean response to item 49 for the principals was 2.89--as compared to 2.58 for teachers. Perhaps concern about resources develops over long periods of time as the concern about refining and improving the use of microcomputers increases. It is possible that the teachers responding to the survey were more concerned about management of educational computing, but later may become more interested in resources. Therefore, we will provide an optional module that emphasizes resources on educational computing.

The close correspondence between the derived factors and factors hypothesized a priori as tentative titles for modules further supports to the validity of the identified essential competencies in computer literacy.

DISCUSSION

Limitations

There are several limitations to this study. First, the five-step process for prioritizing the competencies may be flawed. Although the research of the literature was thorough, it is always possible that not all potential competencies were identified. Furthermore, as microcomputers gain a foothold in education, we can expect a change in the competencies. In the future, new

competencies may be added based on discoveries of teachers, experts, and administrators who are implementing the use of microcomputers in the schools. Second, the competencies could have been interpreted differently by the subjects or, because the original wording of the competencies was retained, some of the competencies may be too general to guide the specification of objectives for the curriculum. Such misinterpretations could result in wide variations in how a particular item is scored. Third, the sample sizes for experts and principals was small, and there was no attempt to categorize the teachers into rural or suburban, or by particular science field or grade level. Therefore, we caution against generalizing the results to all principals, all computer and science education experts, and to all teachers of science (K-12). The goal was not to generalize the results to all science teachers, but rather to identify a set of science and computer educators, administrators, and science teachers sufficiently experienced in educational computing to validate essential competencies; that goal was achieved.

Implications

This study was conducted to establish a definition of computer literacy for science teachers. In 1980, the Minnesota Educational Computing Consortium (Anderson, et al.) suggested that the major component of computer literacy was computer awareness. A year later, Luerhmann (1981) argued that programming should occupy the core of computer literacy. More recently, Barger (1983) suggested that computer literacy include two major components: 1) computer structure and operation, and 2) computer applications and limitations. As a step toward conciliation between those who believe that programming is not part of computer literacy and those who believe the opposite, Barger suggested that a "standard of minimal understanding and ability in programming" (Barger, 1983, p.

112) be added to his two major components. Clearly, there seemed no easy way to resolve the dilemma; yet a resolution was needed to train science teachers to prepare their students to enter the information age. No headway could be made on the design of a curriculum to teach science teachers how to use the computer until the necessary computer literacy competencies could be identified.

As a result of this study, the definition of computer literacy for science teaching has been better clarified and a prioritized listing of 63 competencies has been established. Twenty-four of the 63 competencies were selected as essential for science teachers; 21 were selected as secondary competencies for science teachers; 18 were identified as not necessary for science teachers. The results should be useful to all teacher educators who wish to design materials to train science teachers in how to use the computer for educational purposes. There seems to be little question about the necessity to develop materials to support training of science teachers in computing. According to Okey (1984, p. 18),

> There is immediate need in schools to upgrade skills of science teachers in computing and technology ... this is especially true in science education where computers can make education more effective and provide experiences with the applications of computers in science.

Recommendations

For the future, a number of approaches should be pursued:

1. Other teacher populations should be surveyed so that competencies can be determined for subject matter areas other than science. Once prioritized, these competencies can be used to design modules similar to those planned for the training of science teachers in Project ENLIST Micros.

2. In light of the CBAM model and the discrepancies in ratings between several groups on some objectives, surveys of science teachers who are computer literate and who have been using computers in their instruction for several years should be undertaken. If researchers find a shift in this group of experienced teachers to a higher level of concern, for example about student learning with computers, it would not only tend to confirm the CBAM model, but would give teacher

educators and school district staff developers guidance in developing additions to the five basic teacher training modules and in designing appropriate and effective inservice training sessions.

3. Assess the level of mastery of essential competencies in computer literacy among current science teachers. The literature suggests that this group has not been trained to use computers effectively in their classrooms. Adequate information on this group is needed in order to plan effective inservice programs. Some teachers may need to complete all five planned modules, while others may only need to complete one or two specific modules or perhaps should concentrate on the supplementary materials.

4. Explore the possibility of using the five-step procedure of this study in other curriculum development projects. Curriculum development is not an armchair activity engaged in by a single person far removed from the classroom. Input from classroom teachers, experts in the curriculum area under consideration, and school administrators is needed when initial goals and objectives are being identified and prioritized. Once this step has been accomplished, the design of the curriculum can commence.

5. Explore multiple modes for teacher training materials and activities. Project ENLIST Micros will employ a writing team that will work with project staff, a computer programmer, artists, and media consultants in the development of the curriculum modules. Activities will be selected to motivate the learners and encourage mastery of the content. Although this approach follows the successful BSCS model of curriculum development, there is no assurance that this approach will be completely successful for the development of a teacher training curriculum. Okey (1984) has suggested that modeling, including the use of filmed illustrations of teachers successfully incorporating computers into instruction, will positively influence teachers' behaviors. Such a strategy might be particularly important in training science teachers on the application-type competencies. However, the final answer awaits the implementation and evaluation of the Project ENLIST Micros modular training materials. In the meantime, all teacher educators need to remain open to a variety of training strategies, while working toward a refinement into science of what is largely an art form.

SUMMARY

The results of the study indicate that 24 competencies are essential for science teachers to use the microcomputer in the classroom. Another 21 competencies are important and worth including in a curriculum to train teachers in computer literacy; however, they are a secondary priority. The high consistency of rating of the competencies among the teachers, principals, and experts

strengthens the claim that the competencies are a valid representation of computer literacy requirements for science teachers. The results of the factor analysis further strengthen that claim, because the factors derived from the analysis corresponded closely to the factors hypothesized prior to the study. The essential competencies that make up the factor scales will provide a logical framework for the next phase of the ENLIST Micros project--the development of a mastery test of computer literacy for science teachers and the development of an independent study curriculum for training science teachers to use the microcomputer in the classroom.

Science teachers and science teacher trainers will be more interested in the competencies not ranked highly than those identified as essential for science teachers. The essential competencies fall into the expected categories of Computer Awareness, Applications of microcomputers in Science Eduction, Implementing Microcomputer in Science Teaching, Selection and Evaluation of Software, and Resources for Educational Computing. However, computer programming, the history of computers, and computers and society were not rated as essential competencies.

The secondary competencies may be included as optional enrichment and remediation learning opportunities. The decision to make those opportunities available is consistent with the Concerns Based Adoption Model that indicates that teacher training for a new innovation should provide learning opportunities geared to a variety of concerns appropriate to the teacher's state of involvement in the innovation. The core instruction is geared toward teachers who have never used educational computers; 80% have indicated they have never used microcomputers in instruction (NEA, 1981). Such an approach will ensure that a basic level of competence is achieved by all science teachers who use the

core materials and that additional materials will be available for those teachers who wish to go beyond the essential competencies.

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Table 1 Characteristics of Respondents

CHARACTERISTICS	EXPERTS	TEACHERS	PRINCIPALS
Credits in Computer Science	10.5	6.6	4.5
Credits in Science	34.7	40.7	18.2
Credits in Mathematics	34.3	19.0	12.5
Use computers in education	100.0%	99.2%	96.4%
Taught teachers to use microcomputers in education	89.1%	22.8%	23.4%

Table 2, Descriptive Statistics for Competencies

Group	Percent Important or Very Important	Mean	S.D.	Competency
		Essential Competencies		
Principals	86.15	3.63	.53	55. Use the computer as a tool in the science classroom. This would include knowledge of available software and peripheral interfaced with laboratory apparatus for direct collection of laboratory data, simple data bases for storage of laboratory data, graphing programs for analysis, and use of the computer as a DYNAMIC BLACKBOARD or demonstration apparatus.
Teachers	92.31	3.35	.69	
Experts	97.83	3.28	.88	
Combined	91.73	3.38	.73	
Principals	90.48	3.26	.68	15. Demonstrate ways to integrate the use of computer-related materials with non-computer materials, including textbooks.
Teachers	89.73	3.23	.62	
Experts	91.30	3.24	.78	
Combined	90.20	3.24	.67	
Principals	90.48	3.44	.79	2. Describe appropriate uses for computers in teaching science such as: * computer assisted instruction (simulation, tutorial, drill and practice) * computer managed instruction * computer based instrumentation * computer assisted testing * problem solving * word processing * materials generation and management * information utilization
Teachers	88.28	3.21	.70	
Experts	93.33	3.25	.74	
Combined	89.72	3.26	.73	
Principals	90.48	3.24	.80	25. Respond appropriately to common error messages when using software.
Teachers	89.66	3.23	.73	
Experts	88.89	3.30	.77	
Combined	89.72	3.25	.75	

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.		Competency
Principals	95.31	3.22	.76	4.	Use computer courseware to individualize instruction and to increase student learning.
Teachers	85.62	3.15	.71		
Experts	84.78	3.45	.59		
Combined	87.89	3.24	.70		
Principals	85.94	3.33	.83	*24.	Load and run a variety of computer software packages.
Teachers	88.28	3.28	.70		
Experts	88.89	3.20	.80		
Combined	87.80	3.27	.75		
Principals	85.94	3.28	.67	34.	Understand thoroughly that a computer only does what the program instructs it to do.
Teachers	86.90	3.20	.85		
Experts	88.37	3.17	.75		
Combined	86.90	3.20	.80		
Principals	84.13	3.24	.64	10.	Assist in the selection, acquisition, and use of computers in a science department.
Teachers	86.99	3.22	.82		
Experts	89.13	3.06	.67		
Combined	86.67	3.18	.75		
Principals	85.71	3.48	.66	*12.	Plan for effective pre- and post-computer interaction activities for students (for example, debriefing after a science simulation).
Teachers	82.88	3.10	.72		
Experts	95.65	3.11	.63		
Combined	85.88	3.17	.70		
Principals	96.83	2.89	.85	13.	Plan appropriate scheduling of student computer activities.
Teachers	84.93	3.16	.77		
Experts	71.74	3.29	.63		
Combined	85.49	3.14	.76		

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.	Competency
Principals	93.75	3.28	.83	3. Apply and evaluate the general capabilities of the computer as a tool for instruction.
Teachers	79.45	3.03	.80	
Experts	86.96	3.33	.59	
Combined	84.38	3.15	.77	
Principals	93.65	3.02	.92	8. Plan methods to integrate computer awareness and literacy into the existing curriculum.
Teachers	82.88	3.04	.79	
Experts	75.56	3.32	.59	
Combined	84.25	3.11	.78	
Principals	82.54	3.23	.80	17. Display satisfaction and confidence in his/her use of computers.
Teachers	82.88	3.10	.79	
Experts	86.36	3.13	.81	
Combined	83.40	3.13	.79	
Principals	83.08	3.09	.67	22. Locate commercial and public domain software for a specific topic and application.
Teachers	80.69	2.95	.73	
Experts	82.22	3.00	.64	
Combined	81.57	2.99	.70	
Principals	76.56	3.28	.54	*52. Respond appropriately to changes in curriculum and teaching methodology caused by new technological developments.
Teachers	79.17	2.99	.74	
Experts	95.65	2.86	.66	
Combined	81.50	3.01	.70	

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.		Competency
Principals	84.13	2.93	.65	19.	Value the benefits of computerization in education and society for such contributions as: * efficient and effective information processing * automation of routine tasks * increasing communication and availability of information * improving student attitude and productivity * improving instructional opportunities
Teachers	79.86	2.96	.73		
Experts	80.00	3.05	.81		
Combined	80.95	2.98	.74		
Principals	83.08	3.33	.67	*21.	Locate and use at least one evaluative process to appraise and determine the instructional worth of a variety of computer software.
Teachers	75.00	2.84	.87		
Experts	93.33	3.02	.74		
Combined	80.31	2.97	.82		
Principals	76.92	2.93	.59	37.	Demonstrate an awareness of the major types of applications of the computer such as information storage and retrieval, simulation and modeling, process control and decision making, computation and data processing.
Teachers	77.78	2.88	.82		
Experts	84.09	2.91	.79		
Combined	78.66	2.90	.77		
Principals	82.81	3.09	.64	39.	Communicate effectively about computers by understanding and using appropriate terminology.
Teachers	73.97	2.81	.76		
Experts	84.09	2.97	.89		
Combined	77.95	2.90	.78		
Principals	85.48	3.38	.65	*1.	Describe the ways the computer can be used to learn about computers, to learn through computers, and to learn with computers.
Teachers	70.55	2.88	.88		
Experts	91.11	3.21	.79		
Combined	77.87	3.05	.84		

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.		Competency
Principals	76.92	3.28	.80	40.	Recognize that an aspect of problem solving involves a series of logical steps and that programming is translating those steps into instructions for the computer.
Teachers	74.13	2.92	.85		
Experts	83.72	2.95	.78		
Combined	76.49	2.99	.83		
Principals	76.56	2.75	.72	28.	Demonstrate an awareness of computer usage and assistance in fields such as: * health * science * engineering * education * business and industry * transportation * communications * military
Teachers	78.08	2.95	.79		
Experts	70.45	2.92	.82		
Combined	76.38	2.91	.79		
Principals	73.02	3.00	.84	18.	Voluntarily choose to use the computer for educational purpose.
Teachers	76.71	3.10	.86		
Experts	75.00	3.06	.86		
Combined	75.49	3.07	.85		
Principals	79.03	2.61	.88	11.	Demonstrate appropriate uses of computer technology for basic skills instruction.
Teachers	77.78	2.94	.81		
Experts	63.04	2.95	.86		
Combined	75.40	2.88	.84		

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.	Competency
				Secondary Competencies
Principals	76.56	3.00	.75	46. Identify, describe, and demonstrate the function and operation of various components of computers and related peripheral devices (for example, keyboards, printers, modems, graphics tablets, etc.).
Teachers	72.41	2.74	.96	
Experts	77.27	2.86	.89	
Combined	74.31	2.82	.91	
Principals	71.43	3.15	.52	56. Know by example, particularly in using computers in education, some types of problems that <u>are</u> and some general types of problems that <u>are not</u> currently amenable to computer solution.
Teachers	68.97	2.77	.76	
Experts	93.48	2.73	.60	
Combined	74.02	2.83	.70	
Principals	80.00	3.09	.82	45. Assemble or connect computer systems typically used in instructional situations.
Teachers	67.59	2.75	.96	
Experts	80.00	2.85	.83	
Combined	72.94	2.84	.91	
Principals	68.75	2.73	1.07	26. Make authorized copies of computer software.
Teachers	76.03	3.04	.88	
Experts	62.22	2.77	.73	
Combined	71.76	2.92	.89	
Principals	76.56	2.76	.74	38. Describe ways computer can assist in decision making.
Teachers	67.81	2.67	.81	
Experts	62.22	2.86	.81	
Combined	69.02	2.73	.80	
Principals	76.92	2.48	.91	27. Describe the impact that technological developments have on various career options.
Teachers	68.28	2.78	.87	
Experts	52.17	2.80	.85	
Combined	67.58	2.73	.88	

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.		Competency
Principals	67.19	2.77	.80	44.	Use various diagnostic strategies to ascertain the cause of a malfunction and to determine if the problem is related to hardware or software.
Teachers	66.90	2.65	1.02		
Experts	63.64	2.70	.92		
Combined	66.40	2.69	.96		
Principals	70.77	2.73	.82	53.	Define major computer system components such as: input, memory, CPU, control, and output.
Teachers	65.07	2.68	.89		
Experts	63.64	2.83	.99		
Combined	66.27	2.73	.91		
Principals	74.60	2.73	.79	14.	Describe appropriate instructional arrangements for computer-based learning experiences (for example, physical arrangements and groupings).
Teachers	61.64	2.64	.82		
Experts	68.18	2.81	.95		
Combined	66.01	2.70	.85		
Principals	69.23	2.79	.94	43.	Read, understand, and modify simple programs.
Teachers	64.58	2.67	1.08		
Experts	65.12	2.83	.86		
Combined	65.87	2.73	1.00		
Principals	66.67	2.89	.65	49.	Identify, evaluate, and use a variety of sources of current information regarding computer uses in education.
Teachers	62.33	2.58	.86		
Experts	73.33	2.67	.70		
Combined	65.35	2.66	.79		
Principals	66.15	2.47	.94	23.	Locate and use a variety of evaluations of software.
Teachers	61.38	2.60	.86		
Experts	55.56	2.71	.74		
Combined	61.57	2.60	.85		

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.		Competency
Principals	72.31	2.63	.82	62.	Relate the logic of elementary computer programs to thinking and problem-solving skills taught in the regular K-6 curricula.
Teachers	57.34	2.52	.96		
Experts	55.81	2.89	.79		
Combined	60.96	2.63	.90		
Principals	50.79	2.80	.76	30.	Discuss irresponsible behaviors that may be associated with computer technology such as computer crimes, violation of copyright laws, and unauthorized use of information.
Teachers	63.01	2.66	.93		
Experts	68.18	2.44	.96		
Combined	60.87	2.63	.92		
Principals	60.00	2.71	.69	47.	Evaluate various hardware configurations that might be used in instructional applications, based on software availability and instructional requirements.
Teachers	58.62	2.50	.93		
Experts	62.22	2.63	.65		
Combined	59.61	2.57	.83		
Principals	64.06	2.76	.83	33.	Describe factors limiting the successful use of computers for educational purpose such as: quality of software, quantity of software, cost, hardware limitations, and human factors.
Teachers	55.86	2.54	.90		
Experts	64.44	2.69	.77		
Combined	59.45	2.61	.86		
Principals	73.02	2.80	.75	*6.	Describe unique characteristics of computers that can facilitate learning (for example, non-threatening feedback, learner control, adaptability, and accessibility).
Teachers	47.95	2.38	.75		
Experts	71.74	2.83	.83		
Combined	58.43	2.57	.80		
Principals	54.69	2.56	.96	61.	Determine whether they have written a reasonably efficient and well-organized program.
Teachers	58.04	2.54	1.02		
Experts	60.47	2.56	.92		
Combined	57.60	2.55	.98		

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.		Competency
Principals	74.60	2.39	.87	*9.	Define the elements of a district plan for computer-based instruction, and define the role of the individual instructor in supporting that plan.
Teachers	52.05	2.45	1.00		
Experts	47.73	2.87	.77		
Combined	56.92	2.55	.94		
Principals	53.13	2.64	.77	29.	Discuss some of the positive and negative consequences of computer use in today's society. For example: * machine dependence vs. machine independence * de-personalization vs. personalization * increase vs. decrease in job availability
Teachers	57.53	2.54	.91		
Experts	60.00	2.53	.99		
Combined	58.86	2.56	.91		
Principals	53.13	2.70	1.08	42.	Use a high-level language such as BASIC, Pascal, Logo, or Pilot to read and write simple programs that work correctly.
Teachers	55.94	2.48	1.19		
Experts	60.47	2.58	.89		
Combined	56.00	2.54	1.10		

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.	Competency
		Low-Rated Competencies		
Principals	52.31	2.49	.87	32. Use and teach the unique nomenclature of computing.
Teachers	53.10	2.48	.95	
Experts	55.56	2.38	.95	
Combined	53.33	2.46	.93	
Principals	43.08	2.11	.97	60. Assist students in making informed decisions about choosing careers in digital electronics.
Teachers	56.25	2.19	1.03	
Experts	52.17	2.38	.93	
Combined	52.16	2.22	1.00	
Principals	53.97	2.32	.83	36. Demonstrate an awareness of the different programming languages suitable for science, business, industrial, and educational applications.
Teachers	55.17	2.39	.95	
Experts	38.64	2.46	.82	
Combined	51.98	2.40	.90	
Principals	59.38	2.59	.91	7. Describe a computer-based instructional system as a group of components including software, documentation, hardware, facilities, training, management, and evaluation procedures.
Teachers	44.52	2.33	.87	
Experts	58.70	2.55	.75	
Combined	50.78	2.43	.86	
Principals	56.25	2.45	.82	35. List some of the characteristics that enable computers to be effective at information-processing tasks that require speed, accuracy, and repetition.
Teachers	47.95	2.41	.85	
Experts	50.00	2.44	.85	
Combined	50.39	2.43	.84	
Principals	62.50	2.67	.77	*5. Discuss the effects of computer use on student learning, based on current research findings.
Teachers	41.78	2.24	.82	
Experts	60.00	2.59	.87	
Combined	50.20	2.40	.85	

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.	Competency
Principals	49.21	2.49	.69	51. Demonstrate an awareness of state-of-the-art developments in technology and their potential applications to education.
Teachers	42.36	2.25	.85	
Experts	53.33	2.53	.71	
Combined	46.03	2.33	.79	
Principals	50.00	2.11	.97	59. Write elementary graphics programs and describe how they can be used.
Teachers	43.06	2.19	1.03	
Experts	41.30	2.38	.93	
Combined	44.49	2.22	1.00	
Principals	57.14	2.20	.94	16. Describe possible effects that computer uses in instruction might have on the existing structure of schools.
Teachers	39.04	2.28	.88	
Experts	40.00	2.51	.86	
Combined	43.70	2.32	.89	
Principals	43.75	2.53	.91	41. Demonstrate an awareness of computer systems such as authoring languages and utility programs used for the development of computer-based curriculum materials.
Teachers	35.42	2.16	.91	
Experts	55.81	2.31	.77	
Combined	41.04	2.20	.88	
Principals	31.75	2.49	.87	31. Discuss issues regarding equity of access to computer resources.
Teachers	41.78	2.25	.92	
Experts	48.89	2.25	.74	
Combined	40.55	2.29	.87	
Principals	40.32	1.53	1.10	*54. Describe and give examples of binary and simple logic statements.
Teachers	38.46	2.12	1.08	
Experts	18.60	2.24	.95	
Combined	35.48	2.05	1.08	

Table 2 Descriptive Statistics for Competencies (Continued)

Group	Percent Important or Very Important	Mean	S.D.	Competency
Principals	30.77	1.89	1.06	63. Demonstrate skill in instructional design of courseware.
Teachers	39.44	2.12	.99	
Experts	28.26	2.05	.91	
Combined	35.18	2.06	.98	
Principals	35.38	2.18	.97	48. Describe what producers of instructional materials are doing to integrate computers with other electronic and print media.
Teachers	32.64	2.09	.87	
Experts	43.18	2.18	.83	
Combined	35.18	2.13	.88	
Principals	31.75	2.22	.67	50. Summarize future projections and trends in computer technology.
Teachers	36.55	2.17	.87	
Experts	33.33	2.08	.87	
Combined	34.78	2.15	.83	
Principals	46.88	1.87	1.04	58. Illustrate data flow by simple devices such as logic boards.
Teachers	28.67	1.97	.94	
Experts	31.11	2.31	.91	
Combined	33.73	2.04	.96	
Principals	44.62	2.02	.84	57. Discuss at the level of an intelligent layperson the history of computing, particularly as it relates to education.
Teachers	27.40	1.91	.97	
Experts	31.11	2.23	1.00	
Combined	32.42	2.01	.96	
Principals	18.46	2.18	.89	20. Describe how a computer gets instructions from courseware written in a programming language.
Teachers	25.52	1.95	.93	
Experts	37.78	1.72	.88	
Combined	25.88	1.93	.92	

*$p < .01$

Sources (Texas Education Agency: 1983, Dershem and Whittle, 1980; Taylor, Poirot, and Powell, 1980; Baker 1982; Phillipp, et al., 1982)

Table 3 Factors for Essential Computer Literacy Competencies

Percent Important or Very Important	Factor Loading	Competency
	Factor 1: Computer Awareness	
78.7	.68	37. Demonstrate an awareness of the major types of applications of the computer such as information storage and retrieval, simulation and modeling, process control and decision making, computation and data processing.
78.0	.62	39. Communicate effectively about computers by understanding and using appropriate terminology.
76.5	.57	40. Recognize that an aspect of problem solving involves a series of logical steps and that programming is translating those steps into instructions for the computer.
86.9	.50	34. Understand thoroughly that a computer only does what the program instructs it to do.
76.4	.43	28. Demonstrate an awareness of computer usage and assistance in fields such as: * health * science * engineering * education * business and industry * transportation * communications * military
81.5	.42	52. Respond appropriately to changes in curriculum and teaching methodology caused by new technological developments.

Table 3 (Continued)

Percent Important or Very Important	Factor Loading	Competency
		Factor 2: Computers in Education
89.7	.76	2. Describe appropriate uses for computers in teaching science such as: * computer assisted instruction (simulation, tutorial, drill and practice) * computer managed instruction * computer based instrumentation * computer assisted testing * problem solving * word processing * materials generation and management * information utilization
77.9	.61	1. Describe the ways the computer can be used to learn about computers, to learn through computers, and to learn with computers.
84.4	.31	3. Apply and evaluate the general capabilities of the computer as a tool for instruction.
81.0	.30	19. Value the benefits of computerization in education and society for such contributions as: * efficient and effective information processing * automation of routine tasks * increasing communication and availability of information * improving student attitude and productivity * improving instructional opportunities

Table 3 (Continued)

Percent Important or Very Important	Factor Loading	Competency
		Factor 3: Computers in Curriculum and Instruction
84.3	.51	8. Plan methods to integrate computer awareness and literacy into the existing curriculum.
90.2	.43	15. Demonstrate ways to integrate the use of computer-related materials with non-computer materials, including textbooks.
85.5	.41	13. Plan appropriate scheduling of student computer activities.
81.5	.39	52. Respond appropriately to changes in curriculum and teaching methodology caused by new technological developments.
		Factor 4: Selection and Evaluation of Software
81.6	.68	22. Locate commercial and public domain software for a specific topic and application.
80.3	.57	21. Locate and use at least one evaluative process to appraise and determine the instructional worth of a variety of computer software.

Table 3 (Continued)

Percent Important or Very Important	Factor Loading	Competency
		Factor 5: Attitudes about Computers in Education
75.5	.59	18. Voluntarily choose to use the computer for educational purpose.
83.4	.54	17. Display satisfaction and confidence in his/her use of computers.
81.0	.44	19. Value the benefits of computerization in education and society for such contributions as: * efficient and effective information processing * automation of routine tasks * increasing communication and availability of information * improving student attitude and productivity * improving instructional opportunities
		Factor 6: Computer Use
89.7	.70	25. Respond appropriately to common error messages when using software.
87.8	.59	24. Load and run a variety of computer software packages.
		Factor 7: Special Application of Computers in Education
87.9	.57	4. Use computer courseware to individualize instruction and to increase student learning.
75.4	.42	11. Demonstrate appropriate uses of computer technology for basic skills instruction.

Table 3 (Continued)

Percent Important or Very Important	Factor Loading	Competency
		Factor 8: Teaching Skills
85.9	.60	12. Plan for effective pre- and post-computer interaction activities for students (for example, debriefing after a science simulation).
		Low-Loading Items Not Assigned to Factors
91.7	<.3	55. Use the computer as a tool in the science classroom. This would include knowledge of available software and peripherals interfaced with laboratory apparatus for direct collection of laboratory data, simple data bases for storage of laboratory data, and use of the computer as a DYNAMIC BLACKBOARD or demonstration apparatus.
86.7	<.3	10. Assist in the selection, acquisition, and use of computers in a science department.